USE OF WESTON MU-BEAMS FOR ELECTROMAGNETIC PHYSICS OF HADRONS

Richard Wilson
Harvard University

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It is probable that the 200 GeV accelerator will be used for many experiments in the electromagnetic interaction of hadrons. The parasitic beams will be adequate and no synchrotron of comparable energy is being planned. Some of these experiments will be performed with electron (or tagged gamma ray) beams. These will be discussed elsewhere. But others are well done with muons and these are the experiments which can help to justify a muon beam.

Previous experiments of this sort involving muons are limited to two, both spark chamber experiments and both still being analyzed; the one by Engels et. al. at the AGS and the other by Perl et. al. at SLAC. We note at once, the muon beam available at Weston will be superior to either of these; an 80 GeV μ-beam 10^8/sec with a good duty cycle seems practical. Thus, anything that Engels and Perl can do, we can do better.

We now outline those numbers that are worth obtaining in a "quick" survey--before the fully engineered μ-beam is available. Maybe 10^5 μ per second are available. Two experiments--performed simultaneously--are well worthwhile.

1) Total cross section for interactions of the virtual

photons (almost real) with protons and neutrons. This we measure, as in Engel's AGS experiment by measuring the incident and scattered muon momenta, integrating over scattered directions and correcting for μ-bremsstrahlung and μe scattering. (These last two may be interesting for other reasons and might be measured simultaneously or consecutively.)

The total cross section is as interesting as the πP, KP, etc., total cross sections. We expect a Pomeranchuk theorem to be obeyed but at the present moment, even with this approximation, estimates of the γP cross section at 80 BeV vary from 20 μb to 100 μb. Measurements in progress (Engels et. al., BNL and SLAC) will narrow this, but it remains an interesting number which can easily be measured with the μ-beam of intensity as low as 10^4/sec.

2) Production of ρ mesons by 80 BeV virtual photons. This is also a test of asymptopia combined with vector meson dominance. Roughly, half the total γP cross section is expected to be rho production; the s and t dependence near 80 BeV is of interest for all the models we now have. This, being dominant, is easily measured.

Now we pass to the type of facility towards which we should aim for a final muon beam in order that it can measure electromagnetic interactions well. Some of the experiments here may be advanced to the first group. I here refer to a memo by M. Wong and R. Wilson in "200 BeV Experimental Use" (Vol 3). In this we showed that muons have considerable advantages over electrons for producing beams of tagged (virtual) photons. The advantage is easily stated--there are not so many low energy γ-rays and electrons around, produced by processes of momentum transfer ~ mc. In some experiments this advantage can be a factor $(m_\mu/m_e)^2$. A further advantage may arise from the fact that muons from pion decay are polarized (spin along the direction of motion) and the virtual photons are therefore circularly polarized. In a paper being circulated by Dr. N. Dombey, some features of this are discussed.

I will outline, below, the design of a muon inelastic scattering facility; I specifically say facility because I believe it can do many experiments. The main idea is to measure each incident and scattered muon and assign a virtual photon energy from the difference. If possible the resolution should be 200 MeV - 0.3% in incident energy - so that the number of neutral pions emitted in a reaction may be determined. However, many interesting experiments can be performed with a lesser resolution.

It should probably be possible to work with 10^6 mu mesons per second on a 1 meter liquid hydrogen target. Above this rate, complicated multiple channeling is necessary. Then we expect about 20 nuclear interactions per second. These should all be interesting events! Now the main background events are mu electron scattering (a process which we might, for other purposes, call interesting). It is useful to be able to pick up essentially all the scattered muons from 1/10 full energy to the 0.9 of the full energy. In the Engel's experiment, muons which had lost no energy were excluded to reduce the rate from μe scattering. In a large facility this removal could be done by a coplanarity requirement--measurement of transverse momentum. This was not done by Engels for 2 reasons. (1) it was a lot of work and (2) optical spark chambers were used with a practical limit of one per beam pulse. This requirement would preferably be before any triggering; i.e., by counter hodoscope.

Any event where the muon has lost energy and is not a μe scatter at small angles or a bremsstrahlung event constitutes a trigger. This is the facility. By itself, the facility automatically measures the γP cross section previously discussed. I will outline its further general use.

A series of wire spark chambers, three before a magnet and three after, will measure the angle and energy of recoil protons. These will escape from the target if the energy is greater than 50 MeV. Photoproduction of vector mesons proceeds as exp(-10 t) and t = 0.1 gives 50 MeV recoil protons. We will thus miss the forward direction.

The measurement of angle and momentum gives the missing mass and direction of χ^o in $\gamma + P \to P + \chi^o$ where γ is a virtual gamma ray and χ^o is any neutral object. The resolution in the mass of χ_o will be limited by multiple scattering of the protons to about 40 MeV, but good measures of photoproduction of ρ, ω, and ϕ can be made. We note here that in a search for the weaker of these--the ϕ--there can be a confusing background from coincident detection of a recoil proton and inelastically scattered muon from two independent, more dominant, events. Such chance coincidences can be removed by observing all inelastically scattered muons which is not possible with Engel's apparatus.

It is easy in this arrangement to pick up the decay products of the decaying χ^{o}; there will not be, as in the electron case, a huge background of low energy electrons and gamma rays. Moreover, the use of high energy virtual photons will cause the decay products to peak forwards. We can then pick up these decay products and examine them.

An arrangement for picking up the neutral products is particularly easy (see figure).

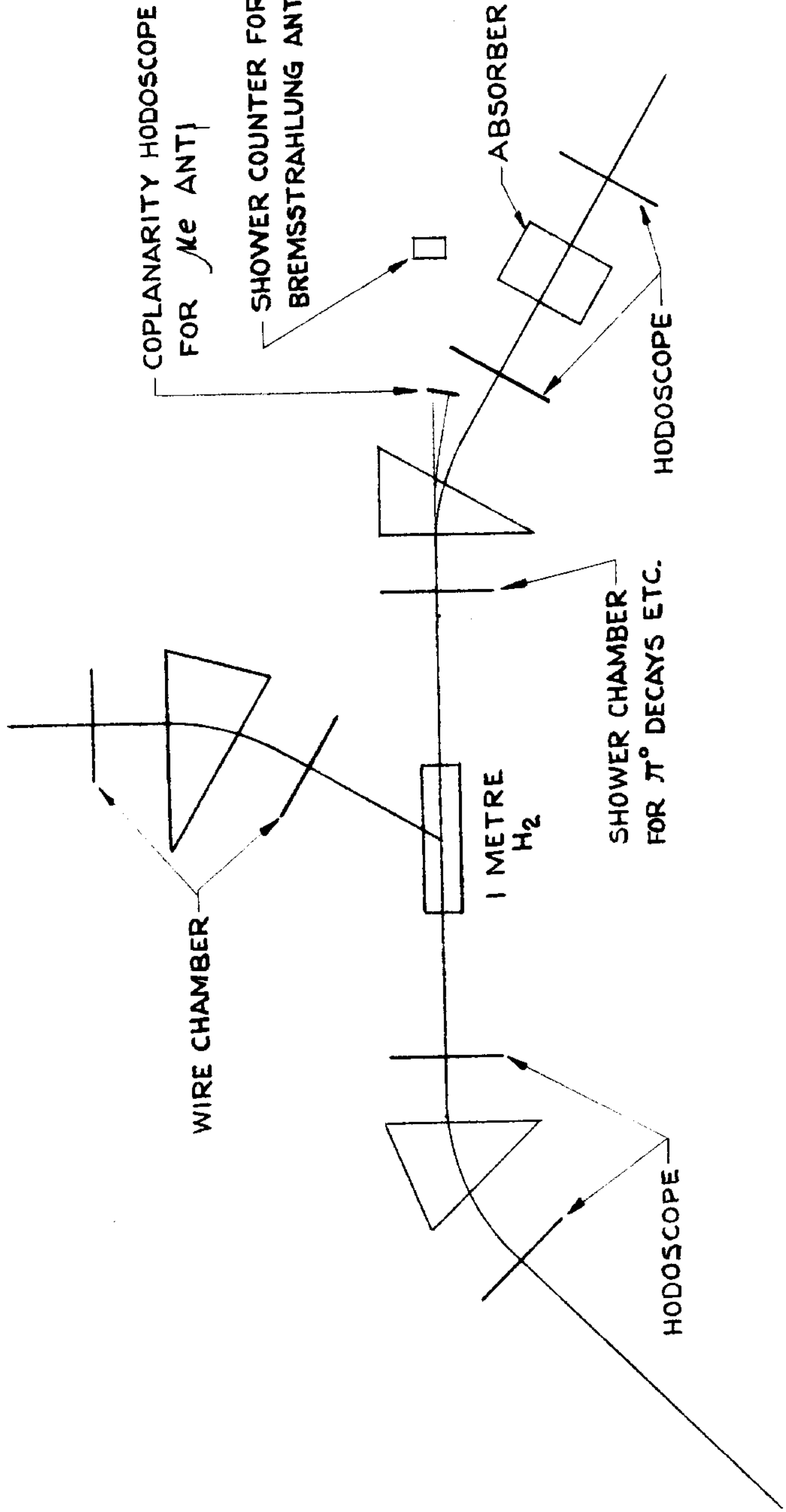
The search for neutral particles detection will be by their showers. If we want to detect charged particles and measure their momentum, we will mix up the μ detection and the charged particle detection. Design work must be done for this.

Two technical advances can be used with advantage with this facility. First, the development of large total absorption shower counters with a few percent resolution at 10 BeV by Hofstadter and others. To go from 10 BeV to 160 BeV in shower detectors one only needs to increase the detector size four radiation lengths--4" of sodium iodide. This may be particularly useful for bremsstrahlung which is not the main subject of this memo.

Second, polarized targets: The muons are polarized; in the first Born approximation this is uninteresting unless the target is polarized also. The target should be polarized in the plane of scattering--and usually along the direction of motion. This needs a cryogenic magnet for the target to enable beam access to be in the right direction. R. V. Pound at Harvard has such a target of ethyl alcohol and water which polarizes the hydrogen to 25%.

Development is continuing of a brute force polarized solid hydrogen target. If present tests on ortho/para hydrogen conversion at low energies are successful, we expect to be constructing a large polarized target in FY '70. We expect 10 to 15% polarization in a 150 kG field at 0.1° K.

Similar advantages accrue to inelastic scattering experiments. Thus, we can measure, by the type of total cross section measurement noted at the start of this memo, the cross section for spins parallel and antiparallel. This is related to the spin dependent term $f_2(\nu)$ in photon Compton scattering by the Drell-Hearn-Garazimov sum rule. It is clearly an interesting quantity. But we can also do this for all the <u>partial</u> cross sections ρ production etc., and this probably becomes a sensitive test of Asymptropia.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